
Status of the MINOS Experiment

(Brookhaven Participation)

BNL DOE HEP program review 04/27/2005

Mary Bishai

`mbishai@bnl.gov`

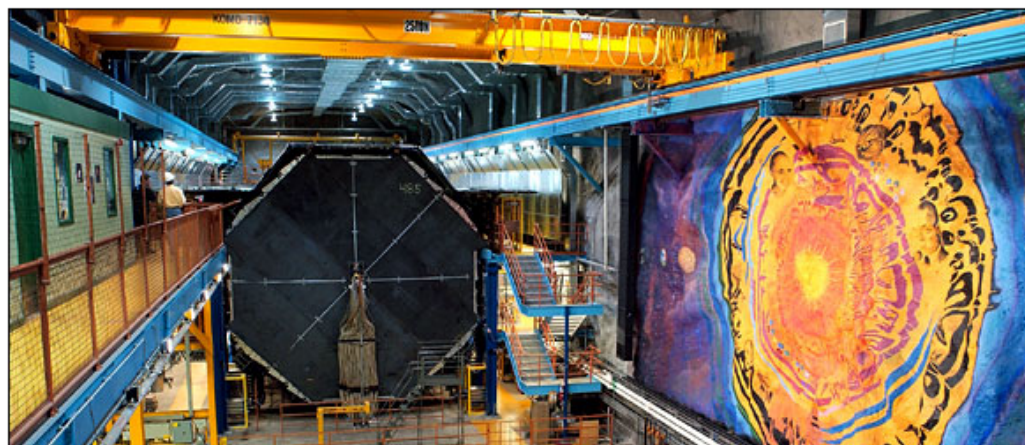


INTRODUCTION TO NuMI/MINOS

From the New York Times

Science, April 26, 2005:

Tiny, Plentiful and Really Hard to Catch



Steve Brunner for The New York Times

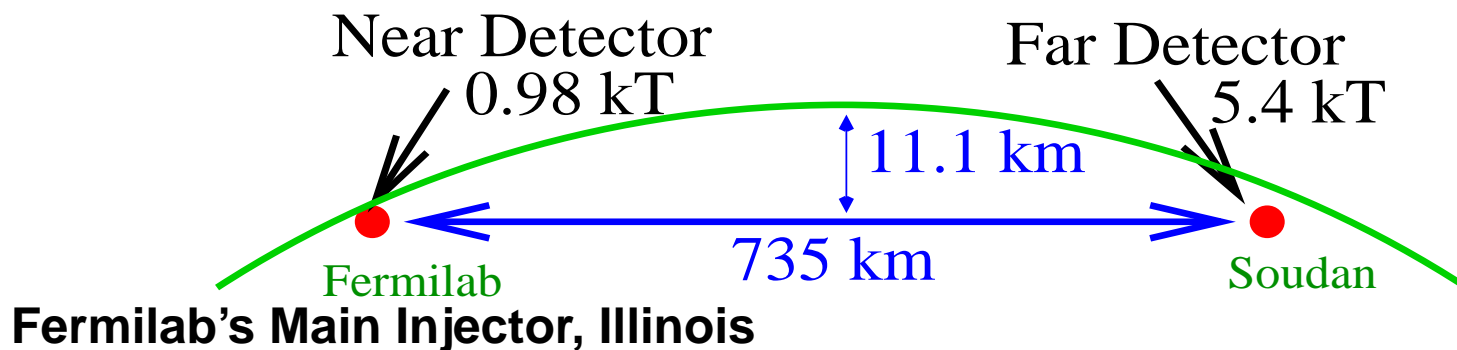
A cavern 45 feet high, 50 feet wide and 270 feet long in Soudan, Minn., formerly an iron ore mine, is now home to a neutrino detector, a \$55 million particle physics experiment.

By [KENNETH CHANG](#)

Published: April 26, 2005



NuMI/MINOS Concept



Soudan Underground Lab, Minnesota

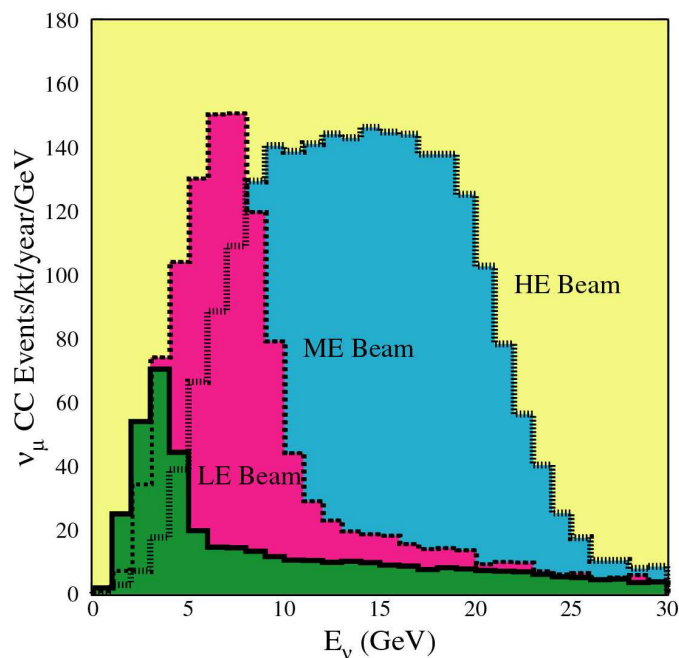
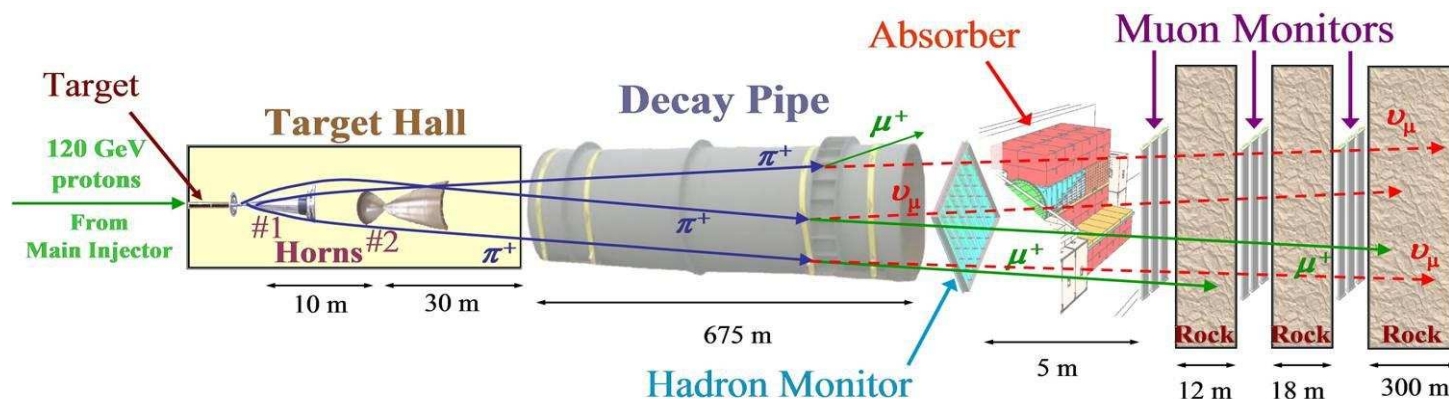


120 GeV protons, 2.5×10^{13} protons/
 $8\mu\text{sec}$ pulse, 1.9 sec rep rate.

⇒ 0.25 MW



MINOS Beam Spectrum

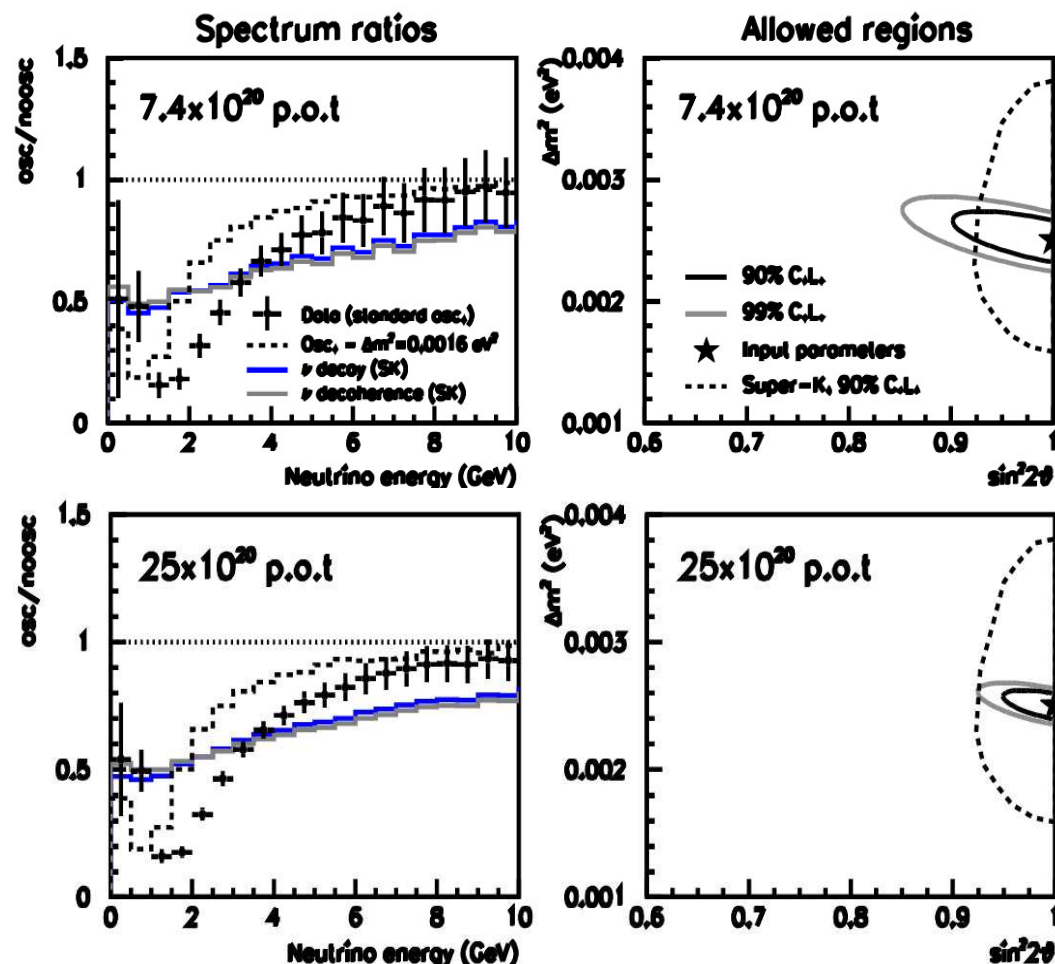


LE beam at 2.5×10^{20} POT/yr \Rightarrow expect 1600 events/yr in FD



MINOS ν_μ Disappearance

- Plot ratio of yield at far det. to expected from near det.
- Location and depth of dip yield δm^2 and $\sin^2 2\theta$
- Assume $\delta m^2 = 0.0025 \text{ eV}^2$, $\sin^2 2\theta = 1.0$



3 years at nominal intensity (top). Intensity upgrades (bottom)

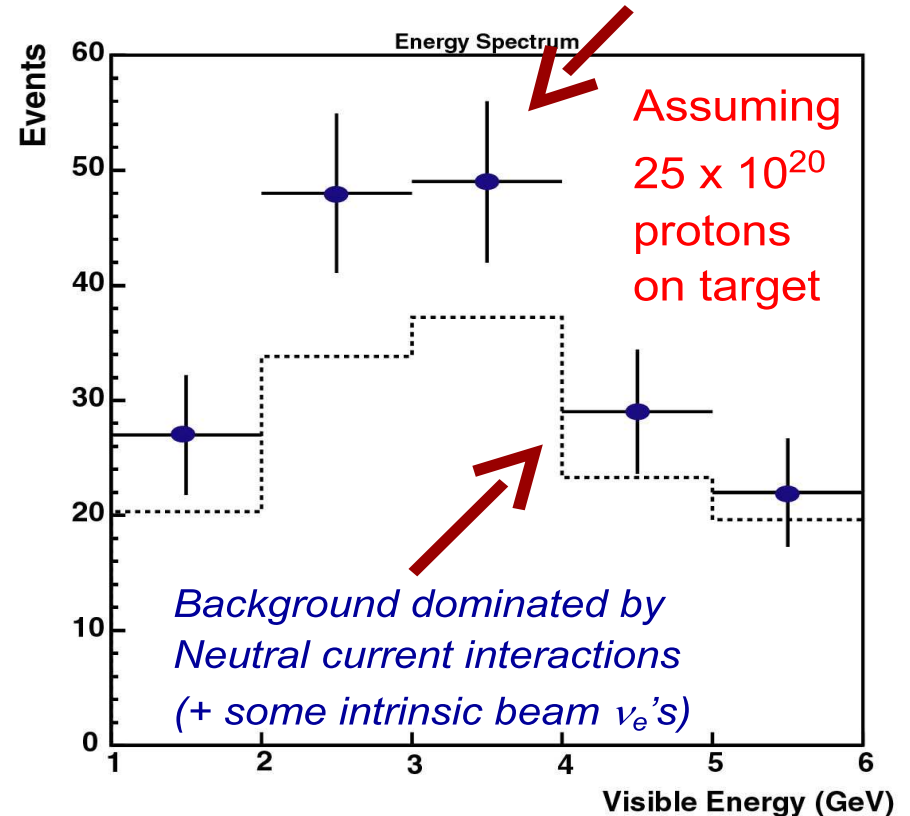
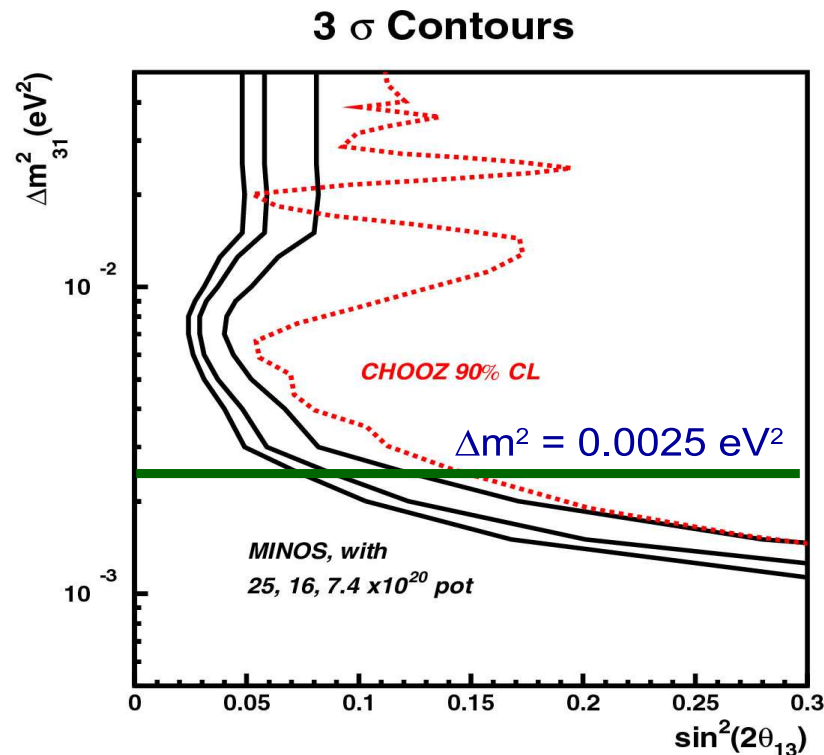
Determine δm^2 to 10 % Rule out exotic oscillation models



MINOS ν_e Appearance Sensitivity

In 2001, NuMI note 714 co-authored by BNL's M. Diwan and B. Viren determined MINOS sensitivity to ν_e appearance.

For $\Delta m^2 = 0.0025 \text{ eV}^2$, $\sin^2 2\theta_{13} = 0.067$



Detection of ν_e at Δm^2_{atm} . Evidence for non-zero θ_{13}



BNL MINOS Collaborators

175 physicists from 32
institutes in 6 countries



Argonne – Athens – Benedictine – Brookhaven –
Caltech – Cambridge – Campinas – Fermilab –
College de France – Harvard – IIT – Indiana –
ITEP Moscow – Lebedev – Livermore –
Minnesota, Twin Cities – Minnesota, Duluth –
Oxford – Pittsburgh – Protvino – Rutherford
Appleton – Sao Paulo – South Carolina –
Stanford – Sussex – Texas A&M – Texas-Austin
– Tufts – UCL – Western Washington – William
& Mary - Wisconsin

BNL:

- **Milind Diwan: Group leader**
- **Brett Viren: joined May, 2000**
- **Mary Bishai: joined July, 2004**
- **Mark Dierckxsens (Research Associate): joined March, 2004**



BNL Contributions to MINOS

- **NuMI Beamline commissioning, monitoring and data logging:**
 - Muon and hadron monitor R&D using the ATF beam (B. Viren, M. Diwan)
 - **Leader, MINOS beamline data logging effort (B. Viren)**
 - Online beam monitoring software (M. Bishai, B. Viren)
 - **Leader, NuMI beamline performance monitoring (M. Bishai)**
 - Incorporating beamline data into MINOS analysis framework (M. Dierckxsens, B. Viren)
 - **Maintaining a significant presence at FermiLab (all).**
- **MINOS databases:**
 - MINOS hardware database framework design. **Overall database management. (M. Dierckxsens)**



BNL Contributions to MINOS

- **MINOS data reconstruction:**
 - Development/maintenance of various offline reconstruction packages including the **event display (B. Viren)**
 - Built BNL physics department co-operative computing cluster \Rightarrow significant MINOS reconstruction and analysis computing capabilities locally at BNL (B. Viren).
- **MINOS data analysis:**
 - ν_e **analysis group co-leader (M. Diwan)**
 - ν_e **analysis software framework development (M. Dierckxsens)**

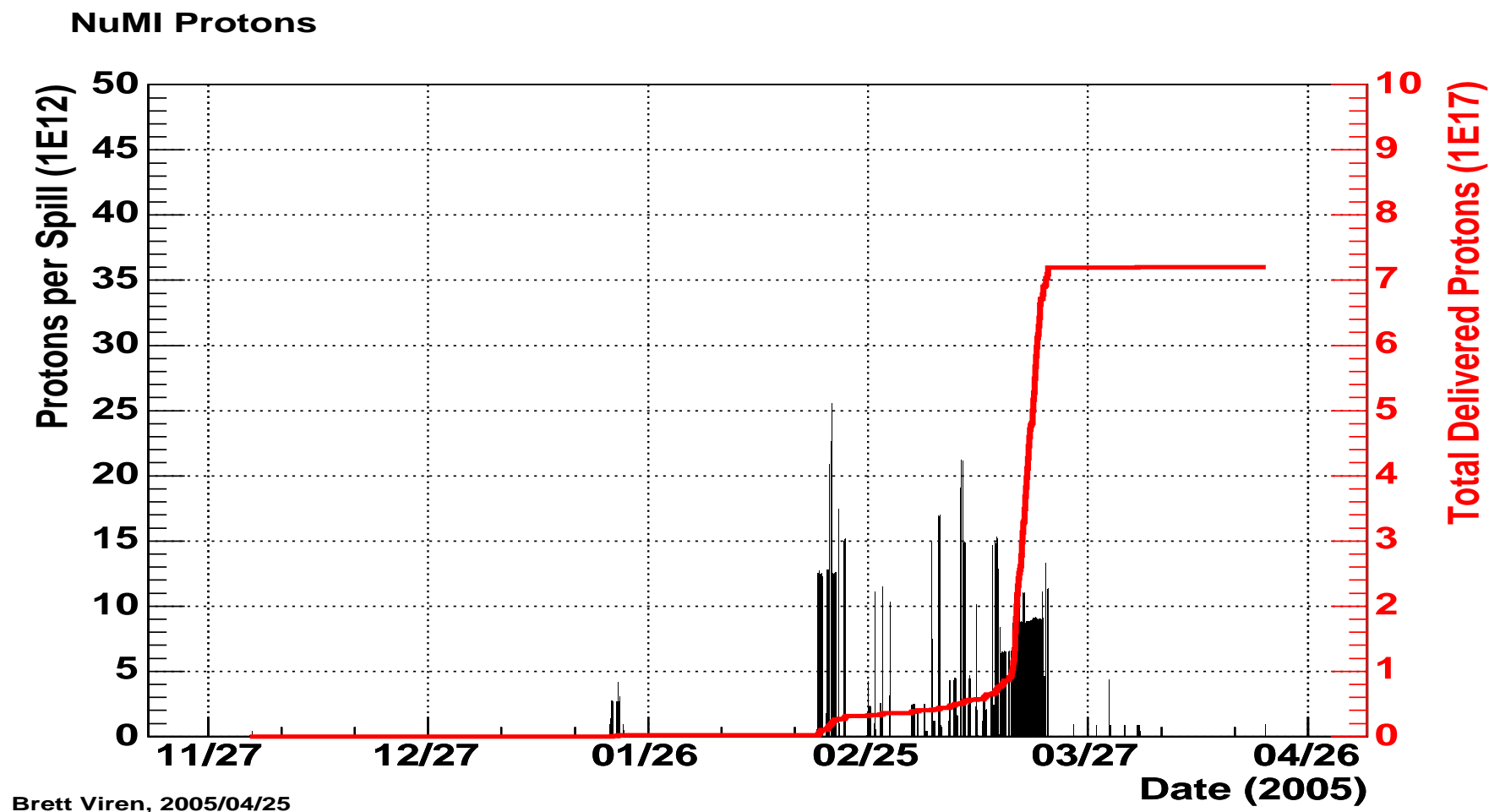


STATUS OF MINOS



NuMI Beamline Performance

Plot from offline beam data logging by Brett Viren, BNL:

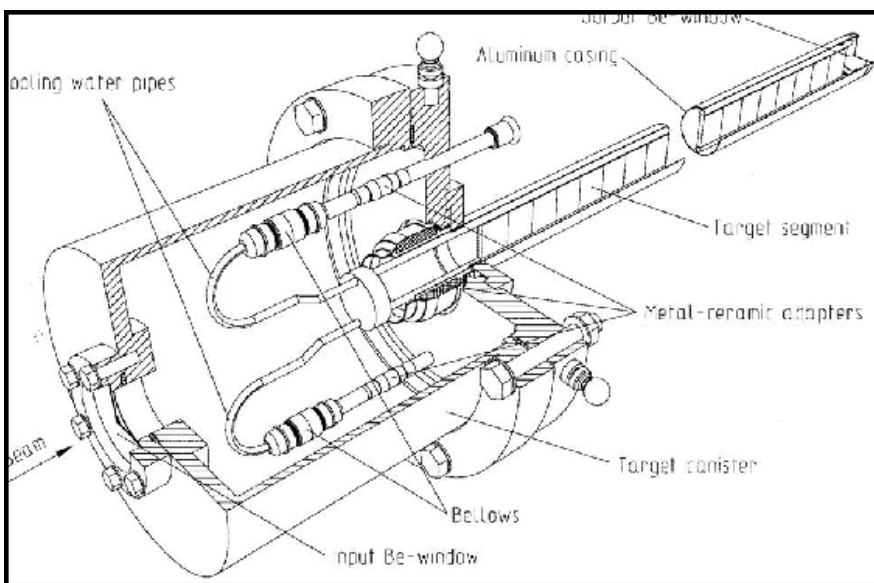
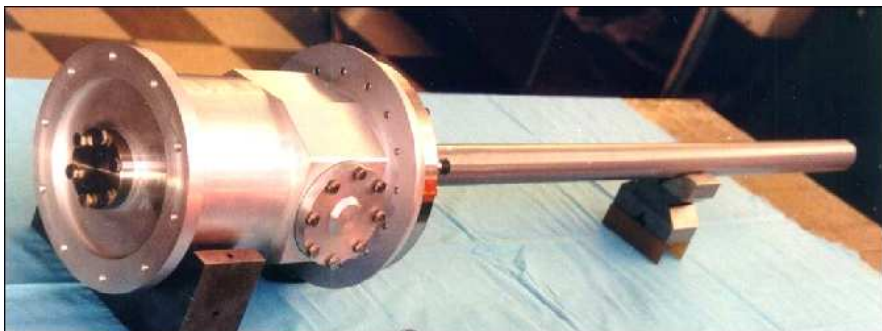


Wed March 23: target vacuum compromised. Cooling water in target enclosure.



MINOS Target Status

Water detected in target enclosure March 23rd.



Target moved into workcell on April 8th. No sign of the leak was found visually and with pressure tests. Moved vacuum port from upstream to downstream to assist in drainage. Target back in beamline circa April 20th.

Expect full intensity beam April 29/30

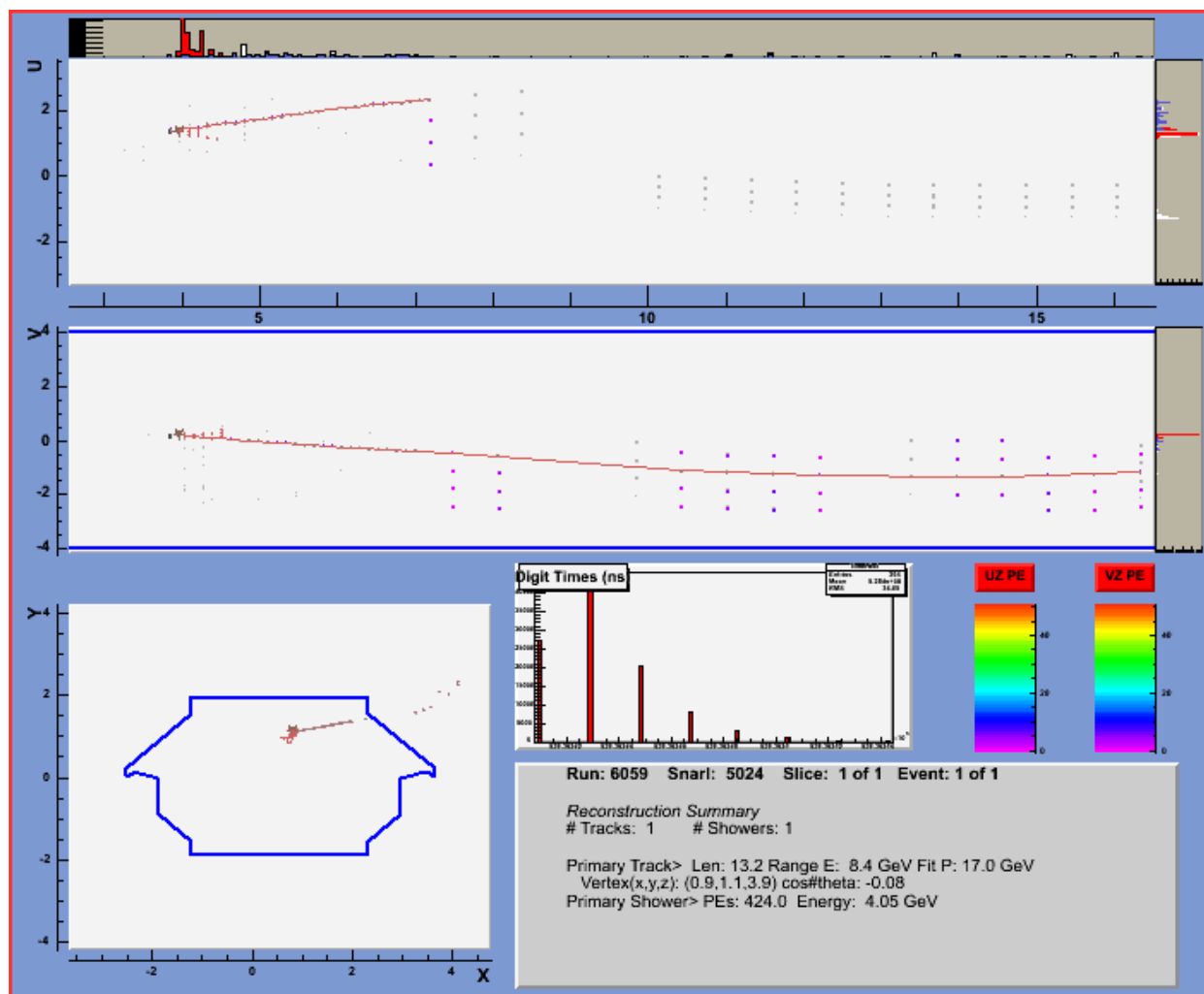


ND 1st Beam Neutrino Jan 21, '05



Intensity was around
 2.5×10^{12} pro-
tons/spill.

Target in the ME posi-
tion.



The official MINOS event display shown was developed by Brett Viren of BNL.



ND Lots and Lots of ν s

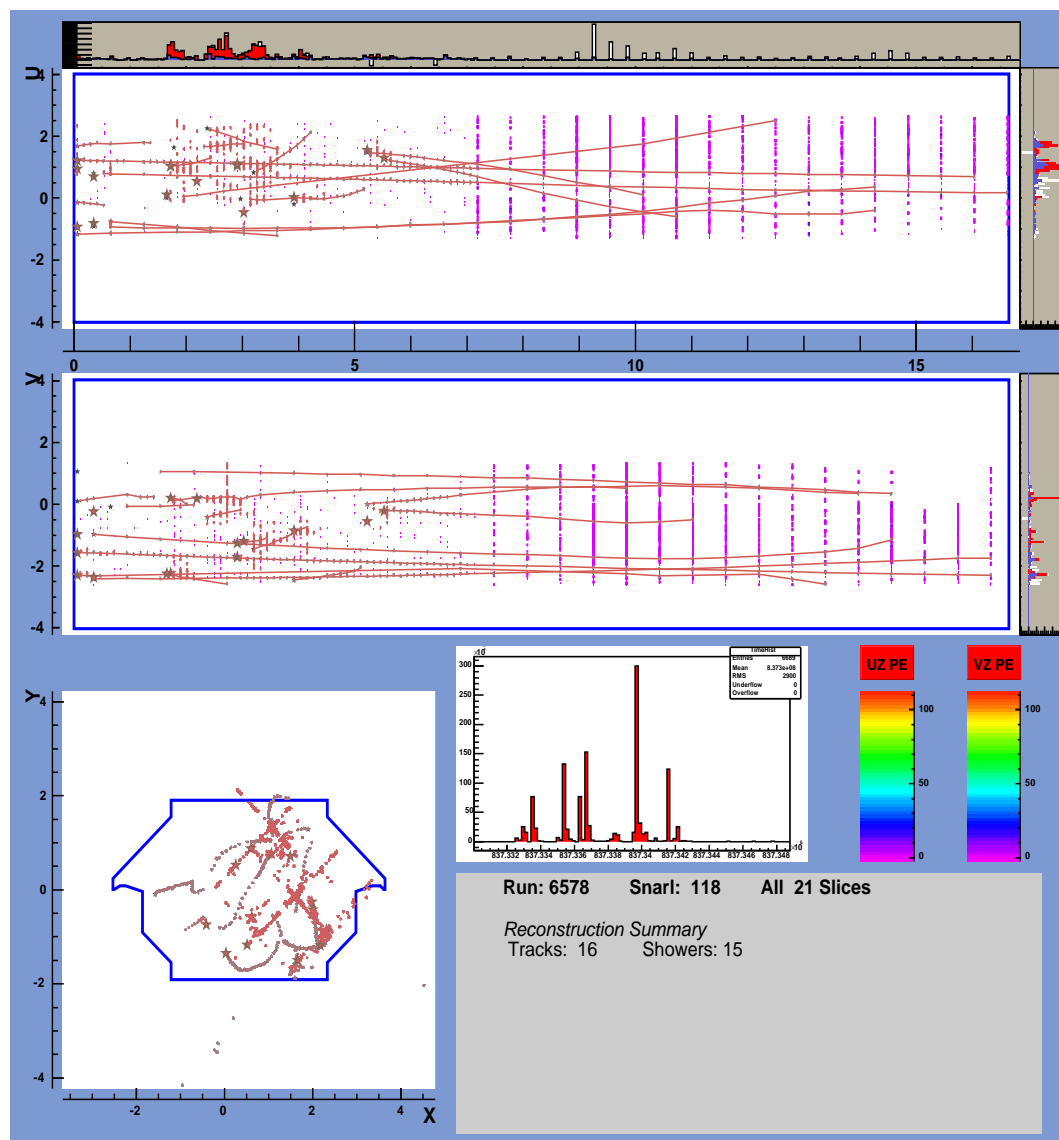
At 2.5×10^{13} p/spill

Target is in ME position.

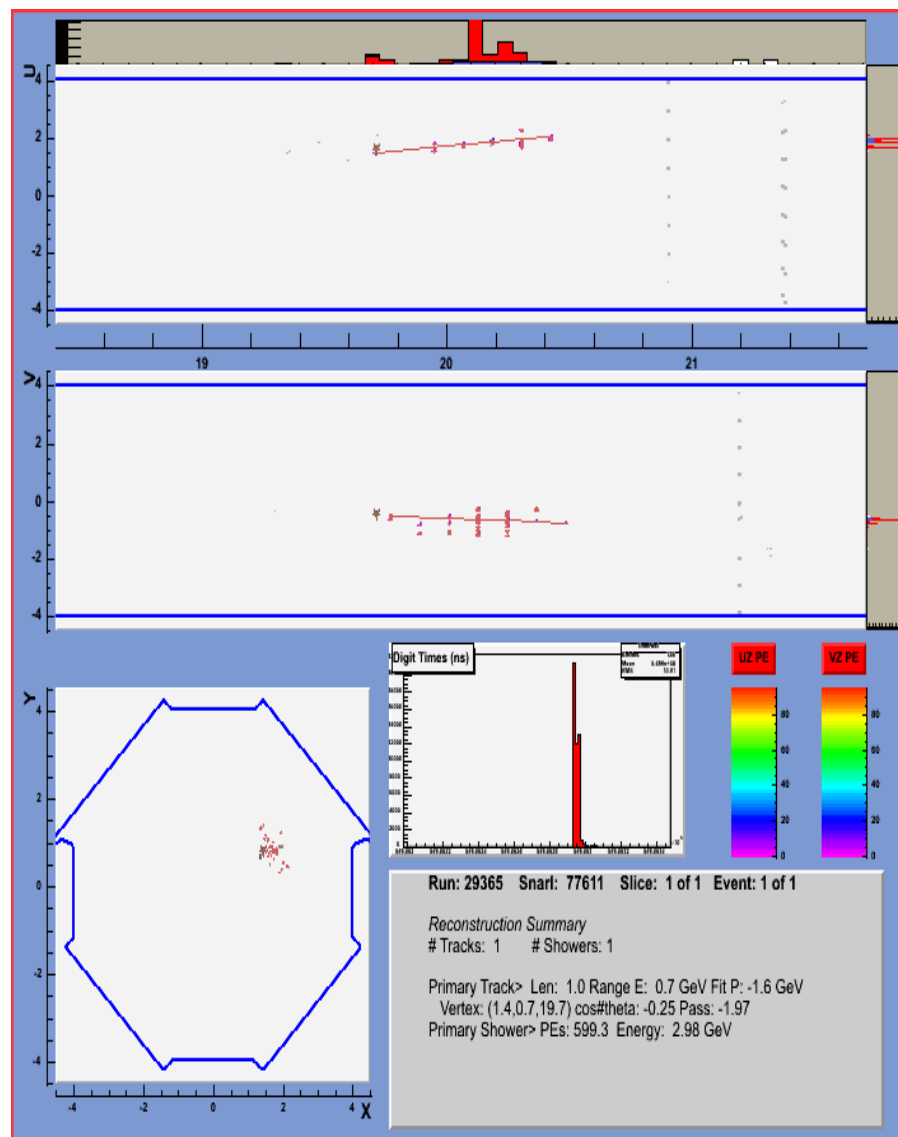
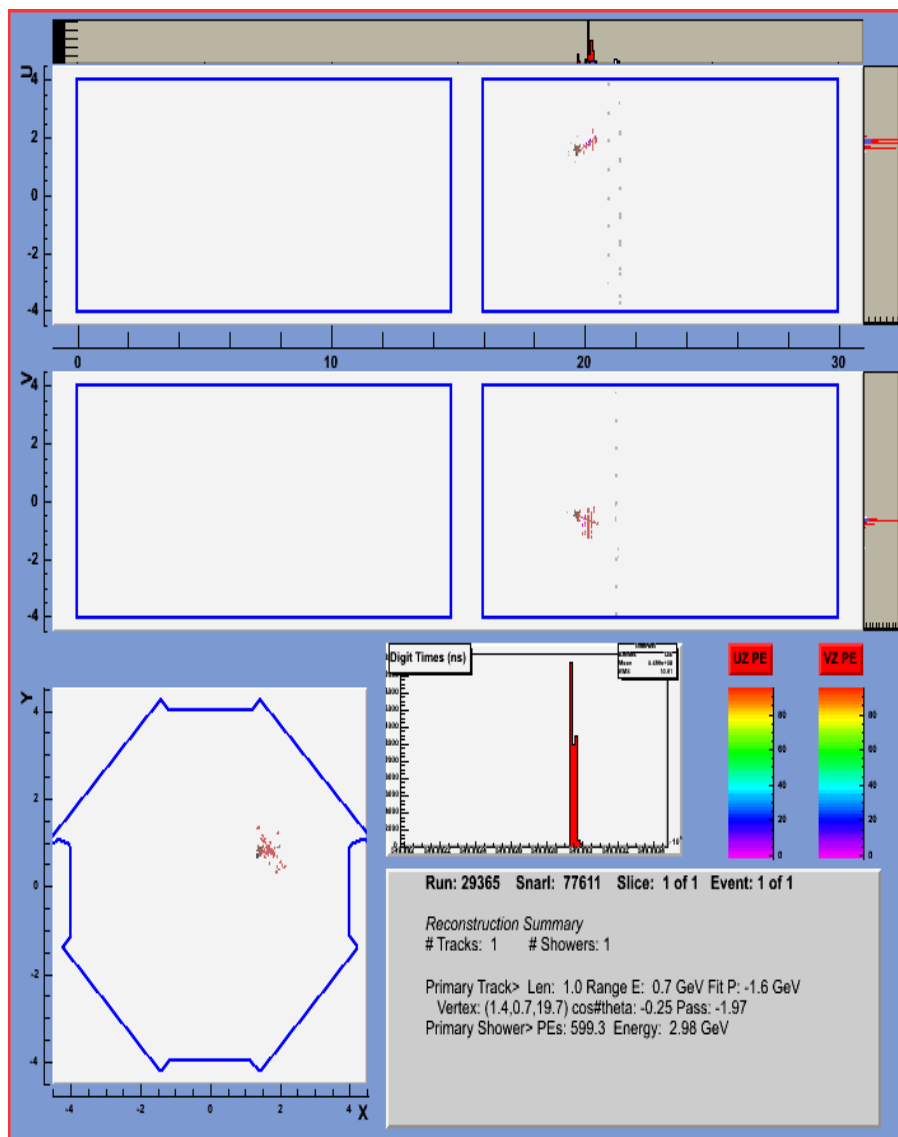
ND scintillator readout has 19ns resolution (same as bunch length).

Timing information is used to separate events.

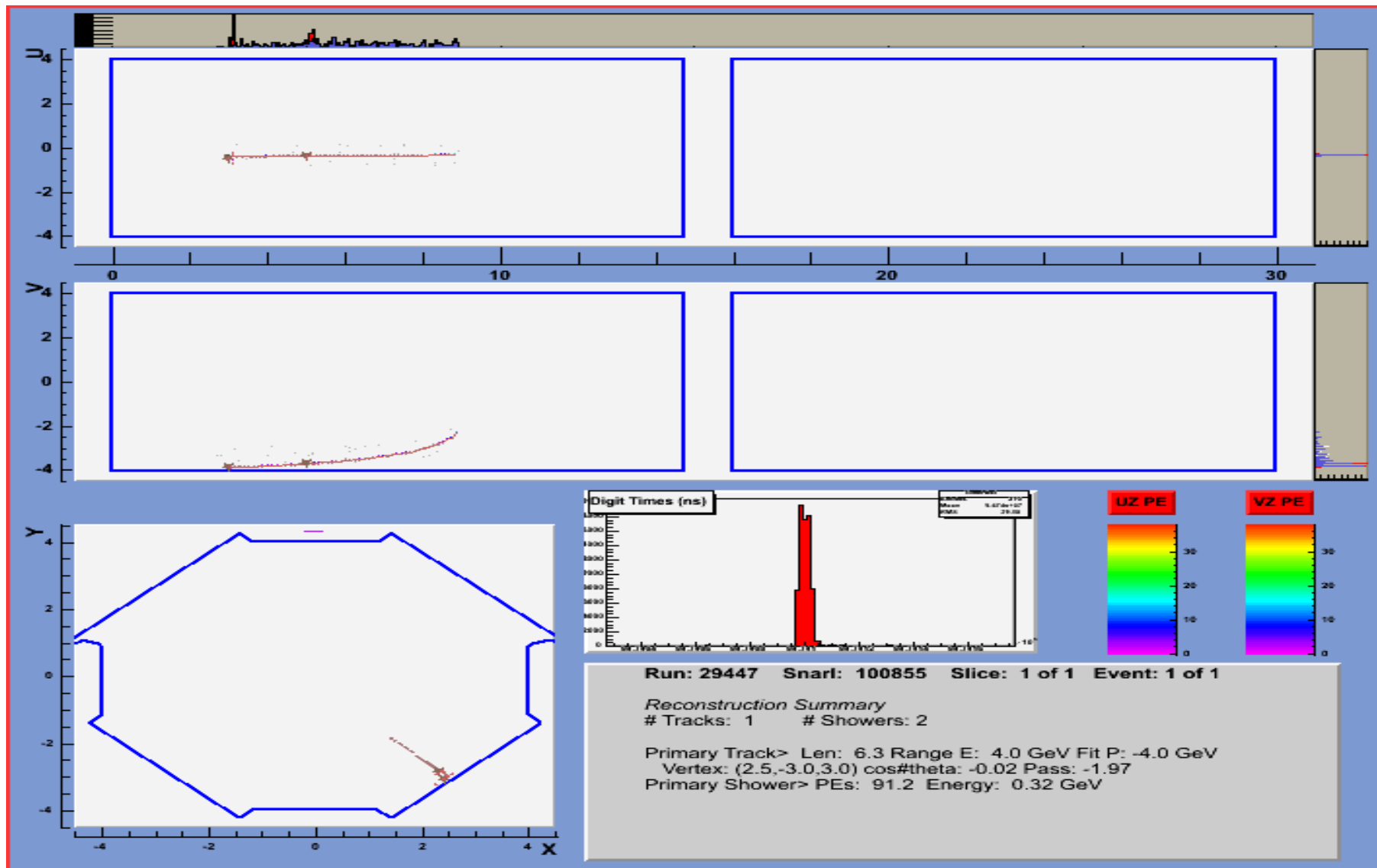
Event display is a critical component of MINOS reconstruction.



1st FD Beam Neutrino, March 7 '05



Far Detector Beam Neutrino #2

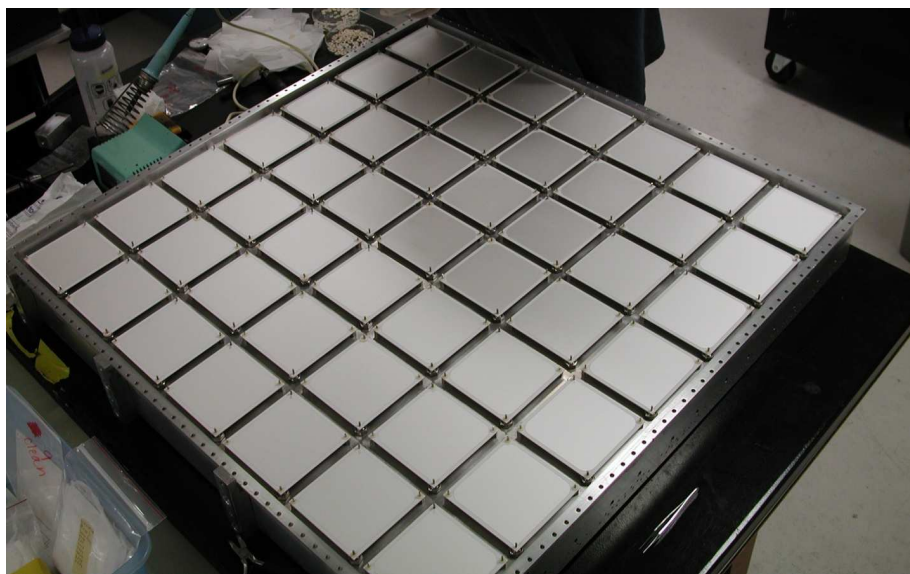
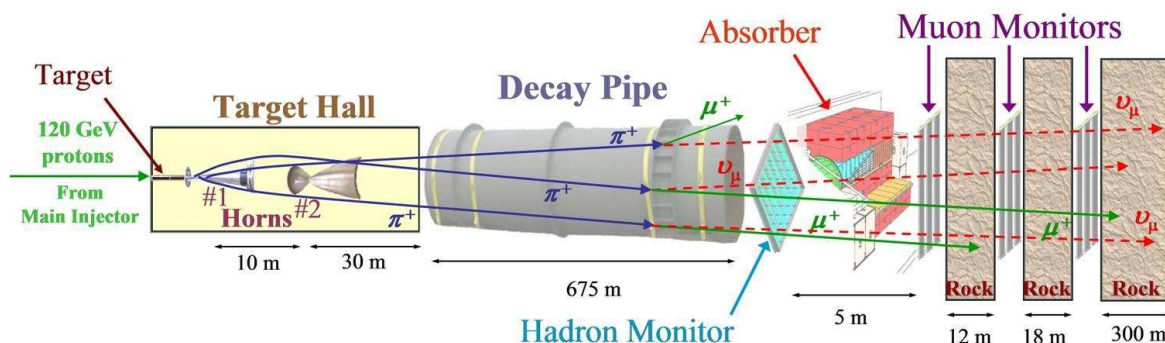


HIGHLIGHTS FROM BNL CONTRIBUTIONS TO MINOS



Muon and Hadron monitors

Pad Ionization Chambers (PICs) used to monitor hadron and muon content of secondary beam. **Developed by BNL/U. Wisconsin/U. Pittsburgh.** Built by U. Texas.



Beamtest of μ /Hadron Monitors

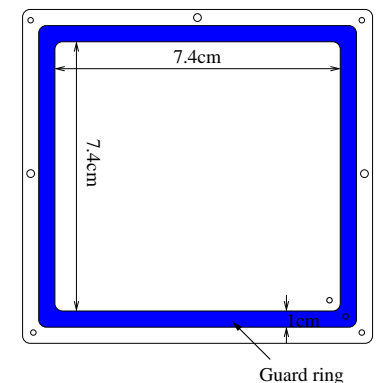
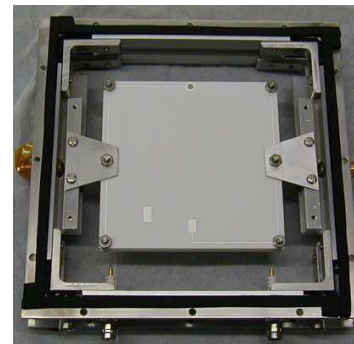
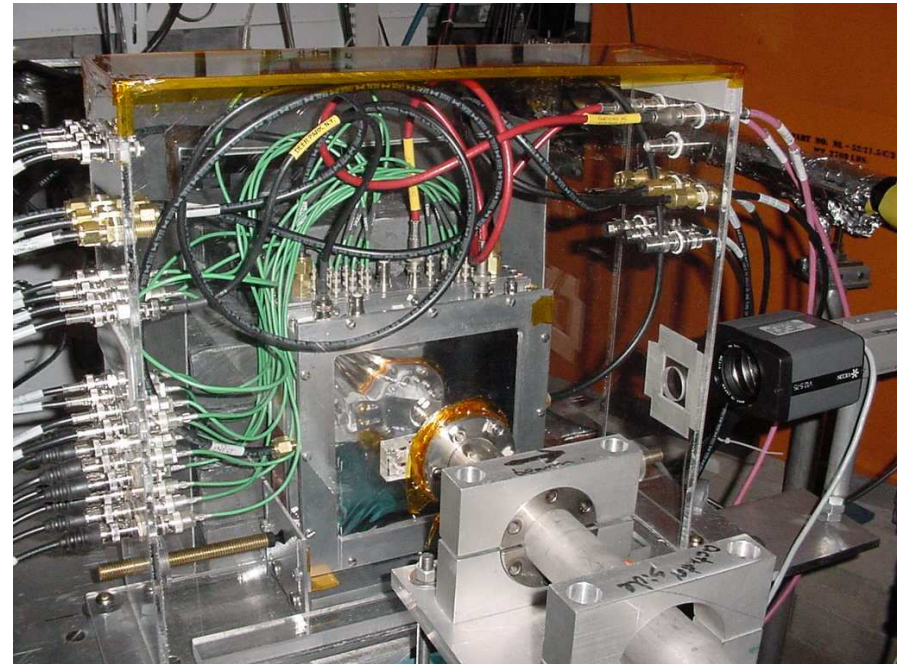
M. Diwan, B. Viren

BNL has been involved with the NuMI secondary beam monitors since 2000

In 2001, BNL conducted 5 beam tests of the PICs used in the hadron and muon monitors using the ATF beam.

Test involved the final ACNET (Accelerator Control Network) electronics and remote readout used in the NuMI beamline.

Results have been published



Nucl.Instrum.Meth.A496:293-304,2003

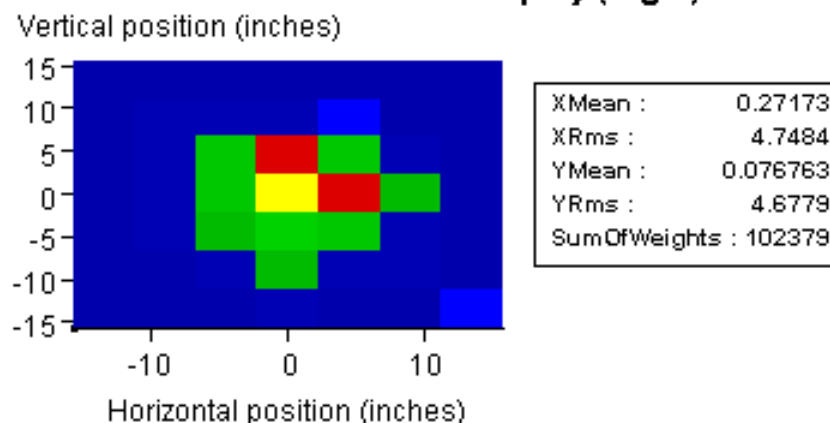


First beam in NuMI using JAS!

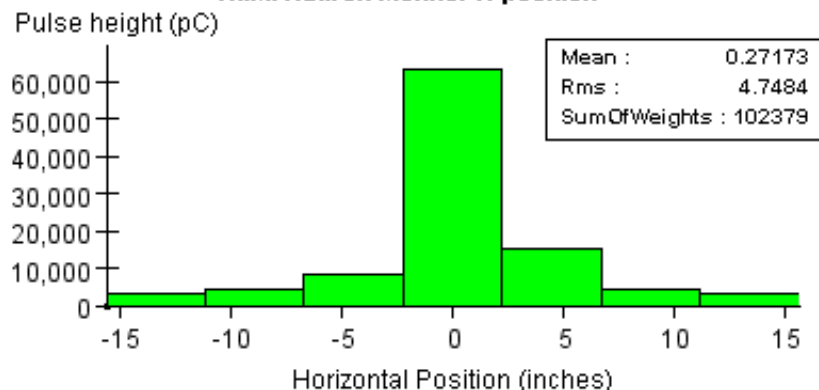
M. Bishai

On December 3rd, 2004 the **Java Analysis Studio (JAS) NuMI Monitor** developed by BNL displayed the first proton beam in NuMI at the hadron monitor on the 12th pulse

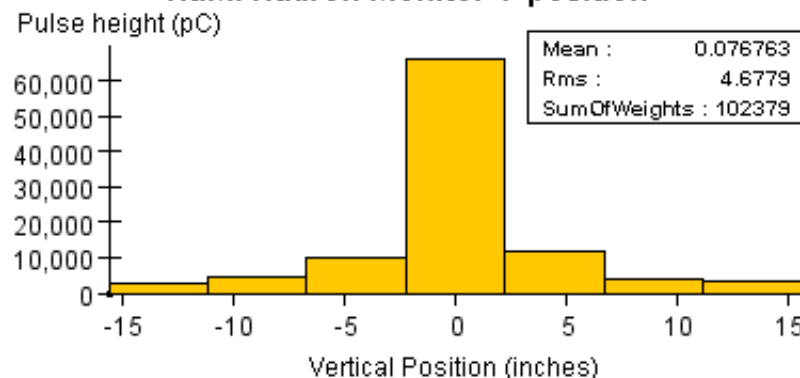
NuMI Hadron Monitor 2-D Display (log Z)



NuMI Hadron Monitor X-position



NuMI Hadron Monitor Y-position

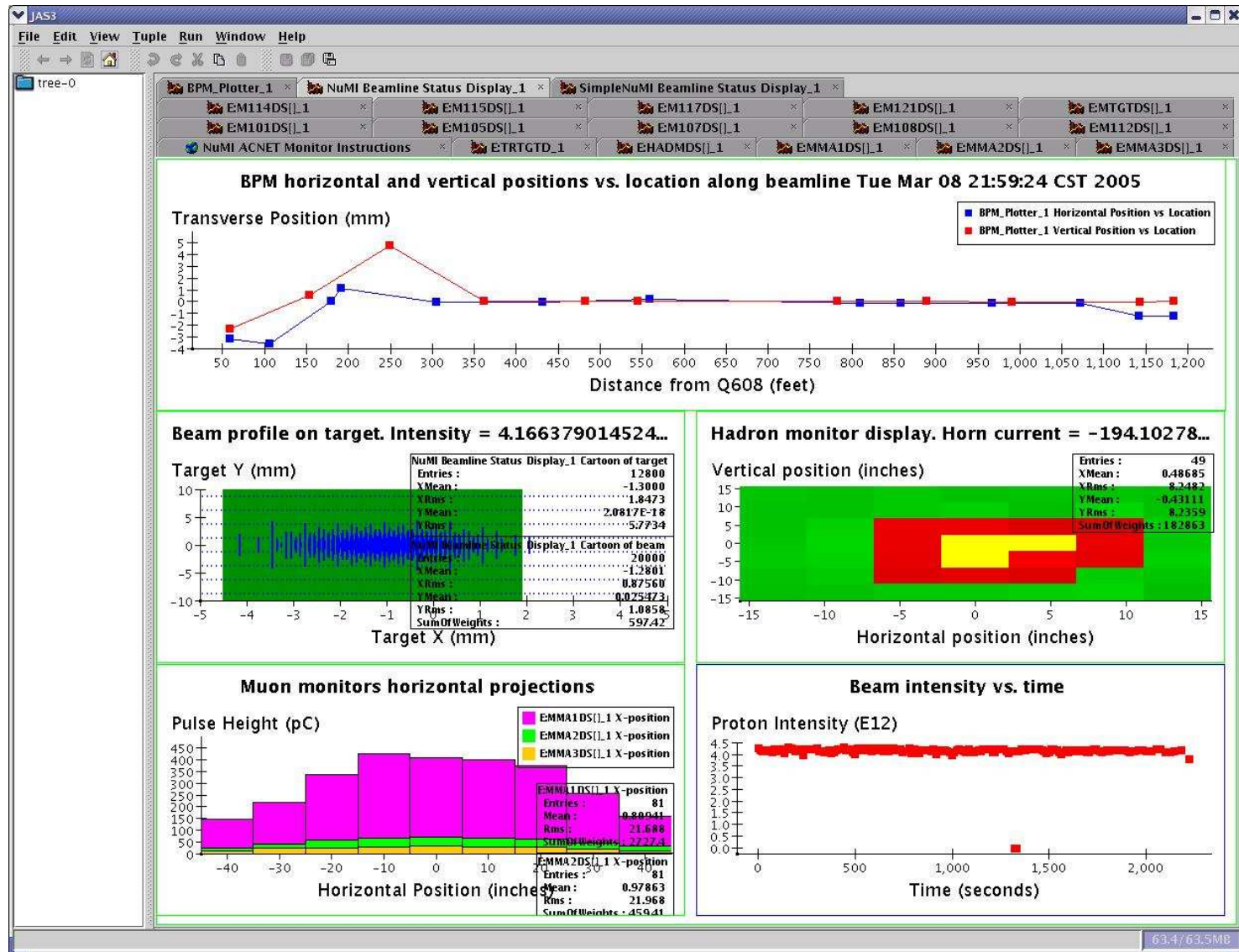


The JAS monitor was crucial during NuMI commissioning.



JAS Online Beam Status

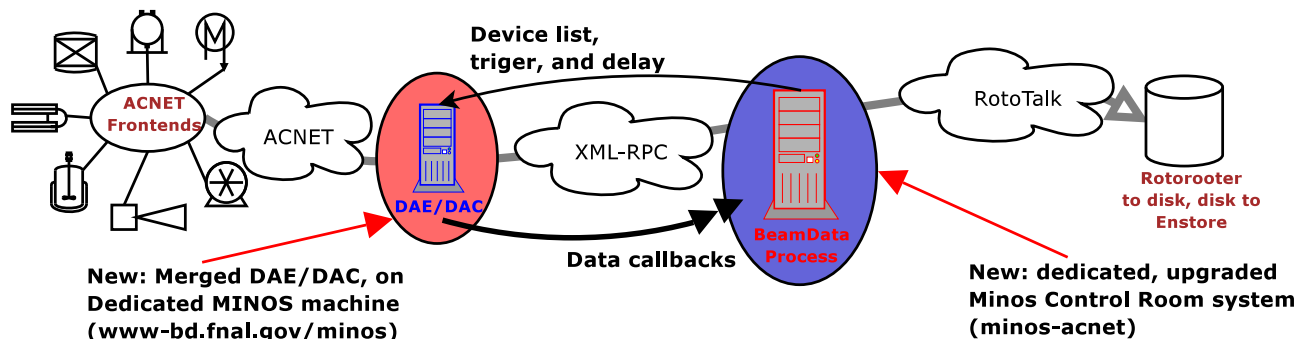
M. Bishai



NuMI beam data logging

B. Viren

Beam data is needed for beam systematics studies and flux normalization.



- There are three main MINOS datastreams: ND, FD and beam instrumentation.
- The BeamData process, written using PYTHON, logs data from ≈ 400 NuMI beamline devices using the XML-RPC server \rightarrow **MINOS data stream.**

The screenshot shows the MINOS control room interface. At the top, there are tabs for 'File', 'Expert', 'View', and 'Help'. Below the tabs, there are two status bars: '✓ server running' and '✓ rotorooter running'. The main display area shows a table of beam data for the file 'B050220_172712.mbeam.root'. The table has columns: Name, Time to next, dT, Count, Sent, Event, Delay, Start Time, and ID String. The first row is 'In-spill' with values: 62.01, 9, 9, 169, 1000, Sun Feb 20 11:27:48 2005, xmlrpc_10230cef66d. Below this, there is a section for 'In-spill' with a table of device data. The table has columns: Name, #seen, #missing, and Description. The rows are: I:PMTGT (9 seen, 0 missing, Profile monitor in or out), I:NUTARZ (9 seen, 0 missing, Location of target), I:K6FTR (9 seen, 0 missing), and E:M118DS[] (9 seen, 0 missing). At the bottom, there is a 'Message Level' dropdown set to 'DEBUG' and a 'Messages to keep' field set to 10.

Name	Time to next	dT	Count	Sent	Event	Delay	Start Time	ID String
In-spill	62.01	9	9	169	1000	Sun Feb 20 11:27:48 2005	xmlrpc_10230cef66d	

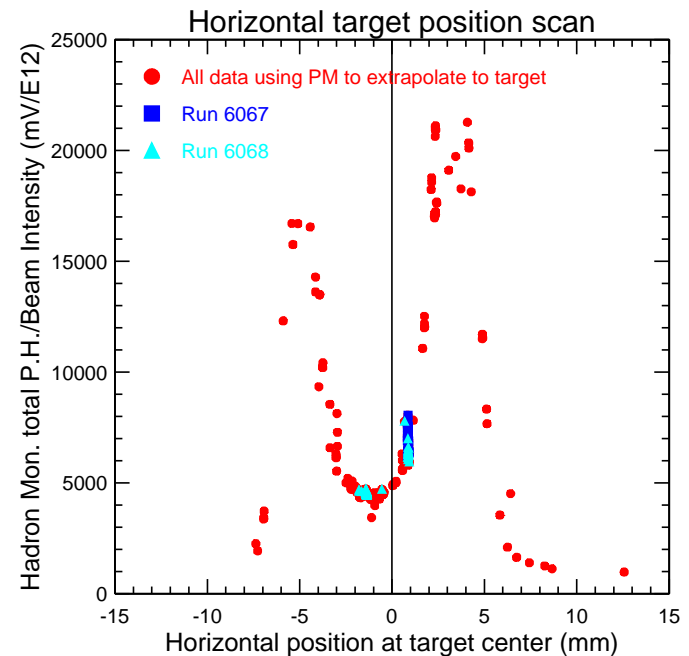
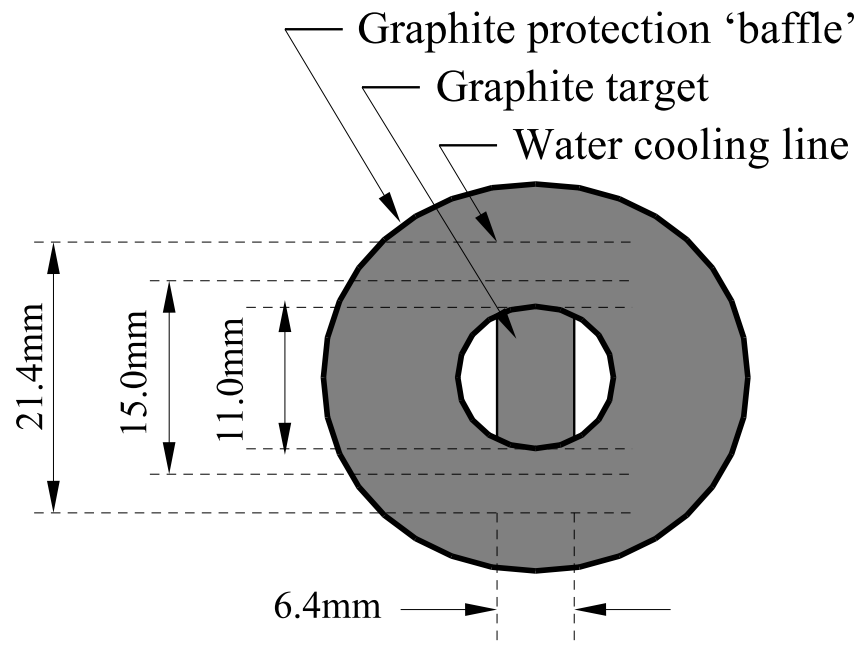
Name	#seen	#missing	Description
I:PMTGT	9	0	Profile monitor in or out
I:NUTARZ	9	0	Location of target
I:K6FTR	9	0	
E:M118DS[]	9	0	



NuMI offline beam data analysis

M. Bishai

This is the first horizontal low intensity proton beam target scan taken on Jan 21st, 2005. Detailed offline analysis first done by M. Bishai using the offline beamdata logged by the BeamData process:



Pulse height in hadron monitor is maximum when beam is passing between target and protection baffle.

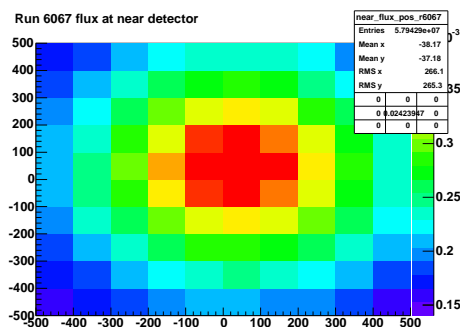
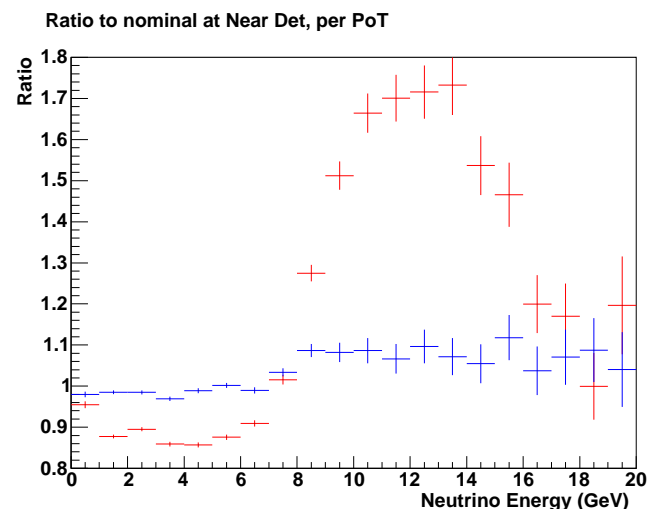


Beam Systematics Study

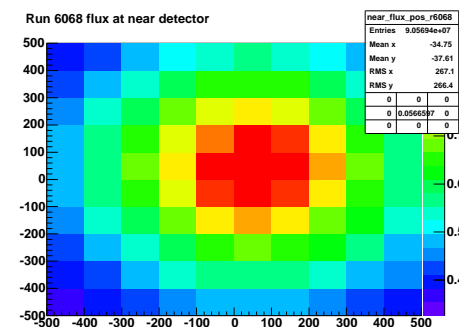
B. Viren

Using data on beam quality from the first two neutrino runs, Brett simulates the effect of the beam movement and compares the ν flux to nominal.

	Nominal	Run 6067	Run 6068
PoT	10e6	4e6	6e6
BeamX0	0	+1.72 mm	-0.59mm
BeamY0	0	+0.41 mm	+0.41 mm
BeamSigX	0.7mm	0.97mm	0.97mm
BeamSigY	1.4mm	1.15mm	1.22mm



Flux Run 6067 (off-center beam)



Flux Run 6068 (on-center beam)

Brett demonstrates that 1.5 mm beam shift = significant systematic.



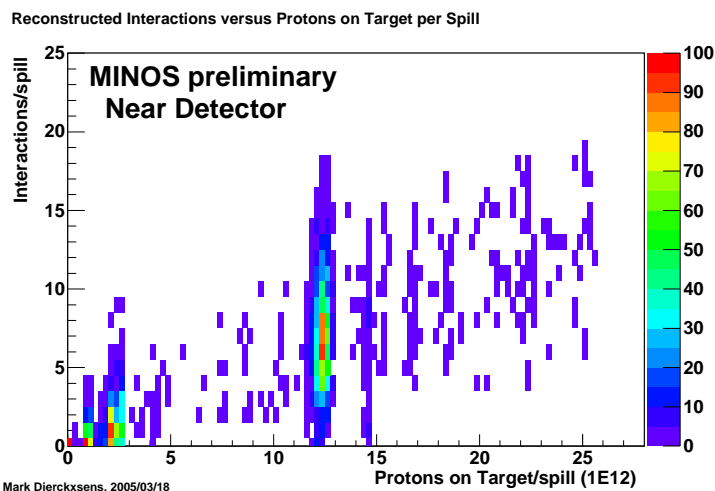
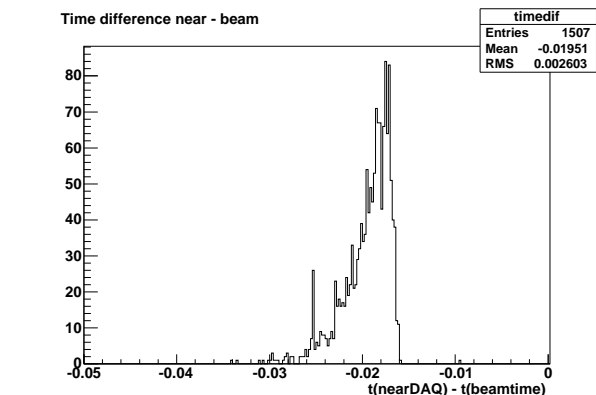
Preliminary ND rate studies

M. Dierckxsens

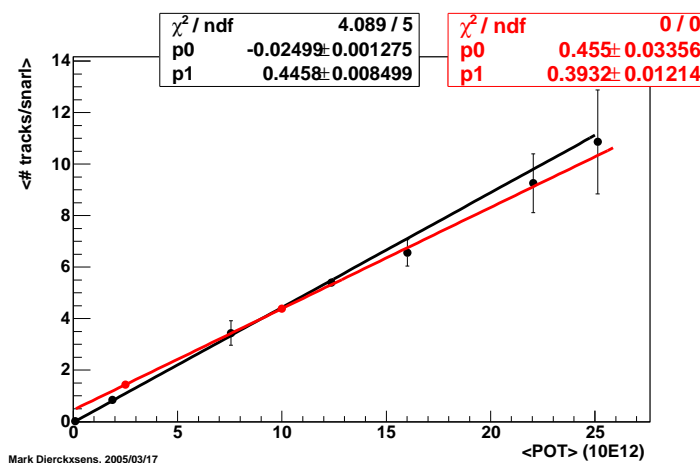
BNL pioneers matching beam conditions with near detector data on a spill-by-spill data using GPS timestamps.

First detailed study of ND rates vs POT:

Difference between ND and beamline timestamps



Number of ν interactions vs POT



Average #tracks/POT data and MC



BNL MINOS GOALS/REQUIREMENTS



Near Term Goals

- **Beamline monitoring and data logging:**
 - Develop JAS program into a beam quality alarm system.
 - Integrate beam data histograms into online MINOS shift framework.
 - Spill-by-spill beam conditions in MINOS ntuples and databases.
- **Physics goals:**
 - Set new ν oscillation limits using observed rate in the ND as a short baseline experiment.
 - ν_e reconstruction in the near detector.
- **Publications:**
 - Joint NIM publication on NuMI beamline commissioning. BNL, U. Texas at Austin and FermiLab.



Summary & Conclusions

BNL's long term MINOS goals are:

1. **Normalization of the ν rate using beam data.**
2. **Searching for ν_e appearance in the far detector.**

BNL has been a leading contributor to the MINOS effort since 2000, particularly in developing the beamline instrumentation and beam data monitoring and logging software.

With the addition of two more BNL collaborators last year, we have also taken a leading role in MINOS database development and management and beam data online monitoring and analysis.

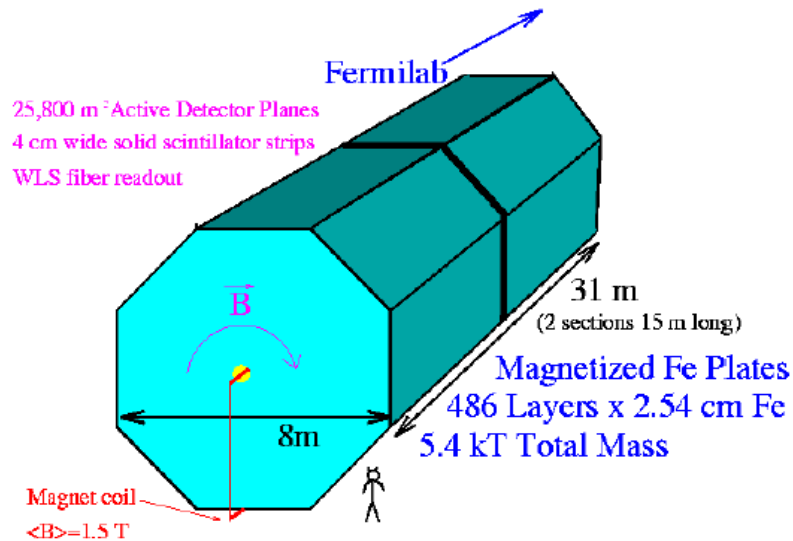
BNL has pioneered matching beam conditions with near detector data to study ND neutrino rates. **Lots of work done and lots more to do!**



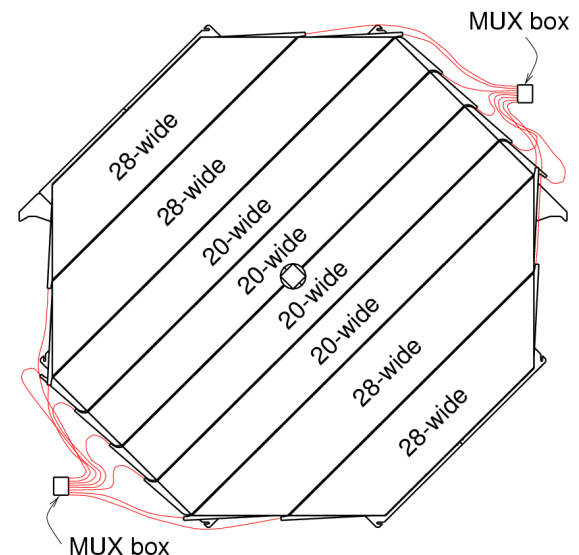
BACKUP



The Far Detector



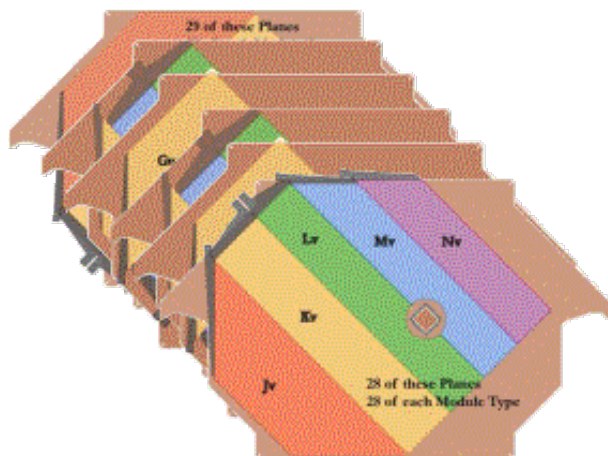
- $8\text{m} \times 2.54 \text{ cm}$ thick Fe plates
- $4.1 \times 1 \times 800 \text{ cm}$ scintillator strips with WLS fiber readout
- Toroidal B -field, 1.3 T at $r = 2\text{m}$
- Cosmic μ veto shield



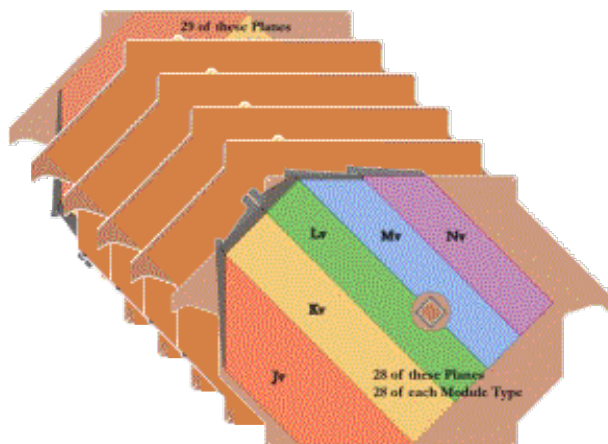
486 layers \Rightarrow 5.4kTon



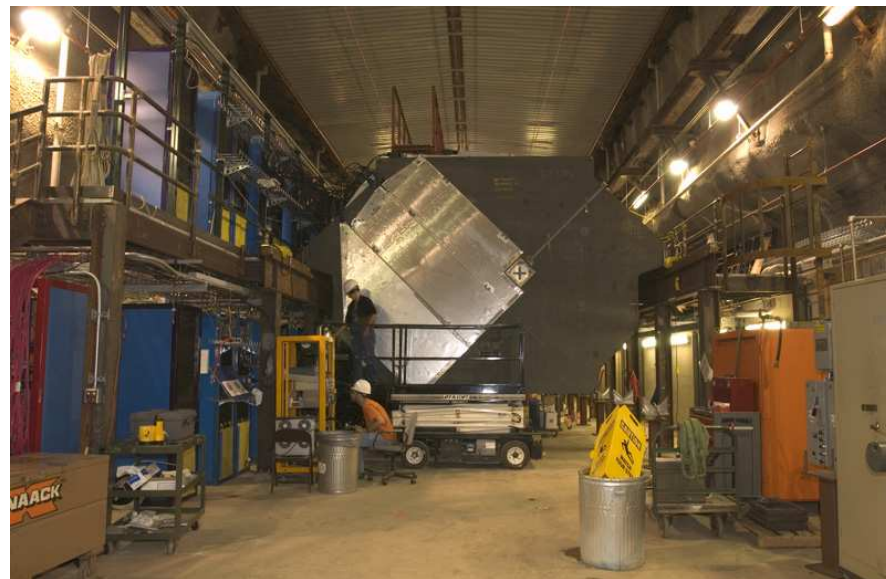
The Near Detector



Calorimeter region



Spectrometer region



NuMI Primary Beamline



Transport
Line Q115



Transport
Line Q114

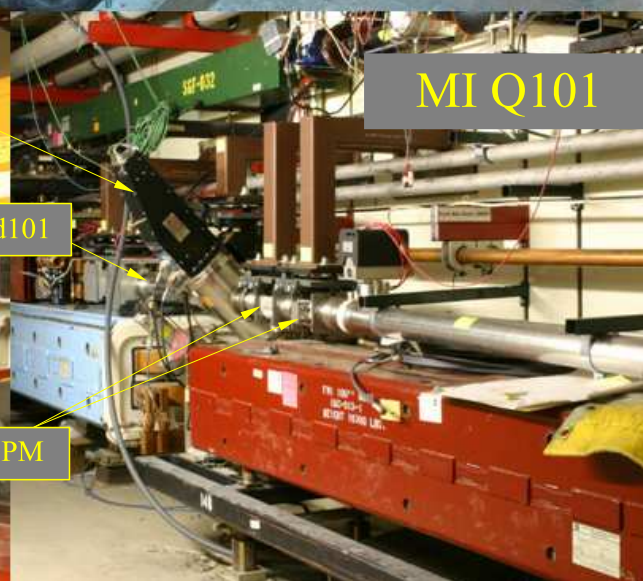


MI Q105

SEM

Toroid101

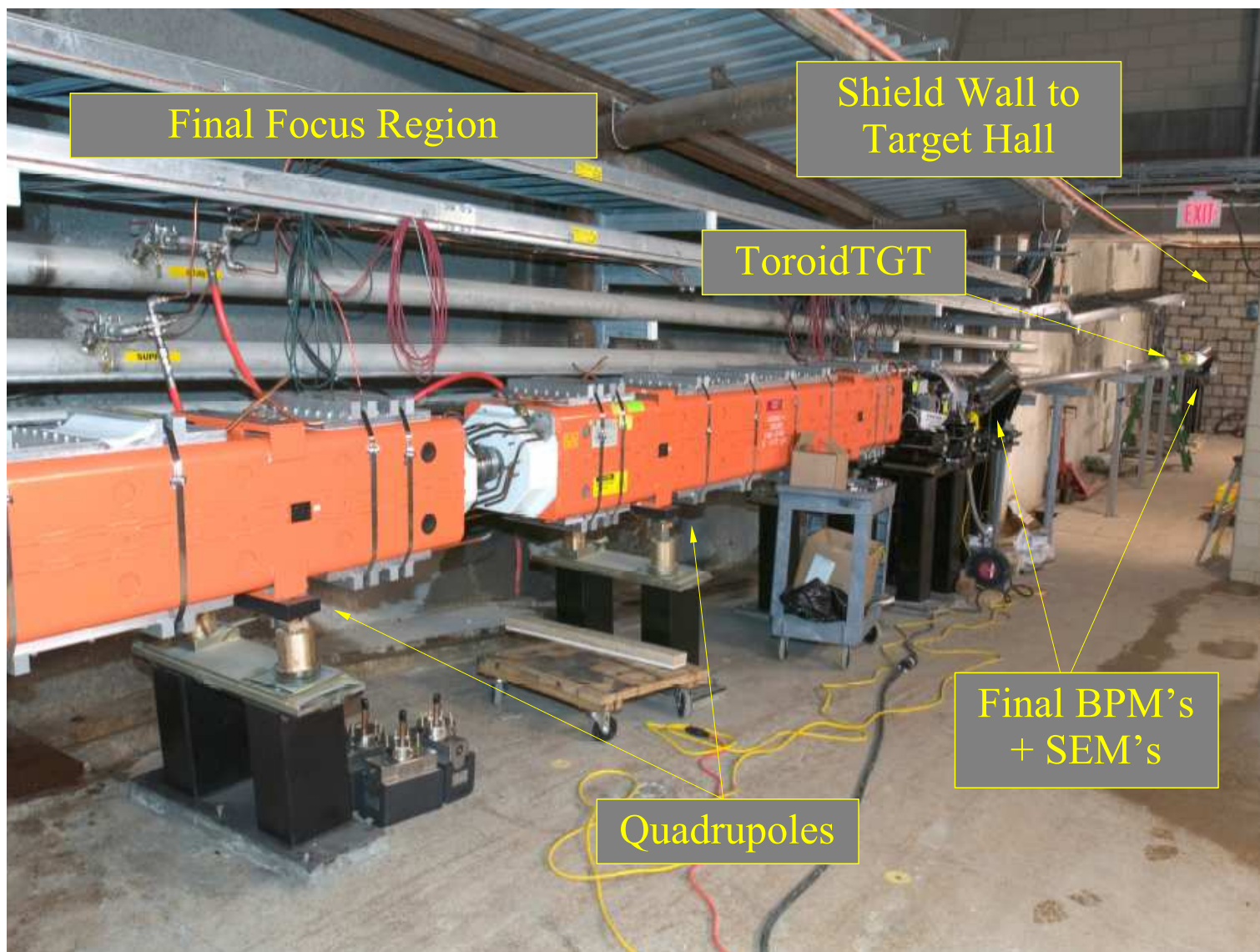
BPM



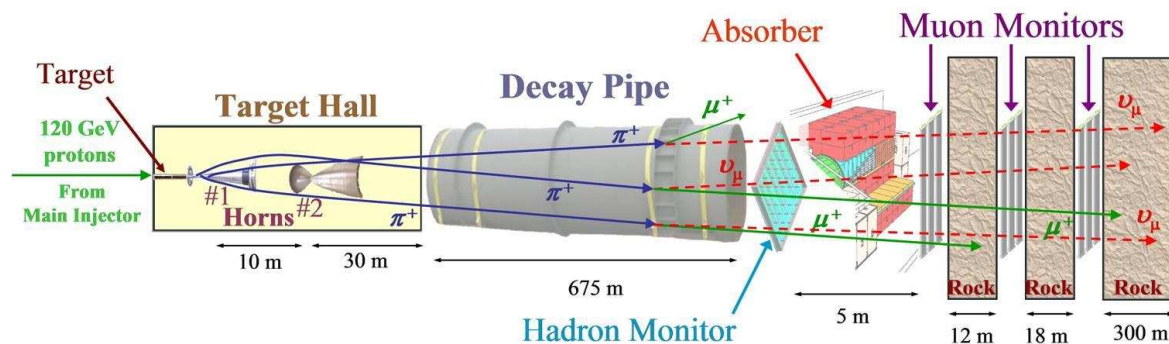
MI Q101



NuMI Pretarget

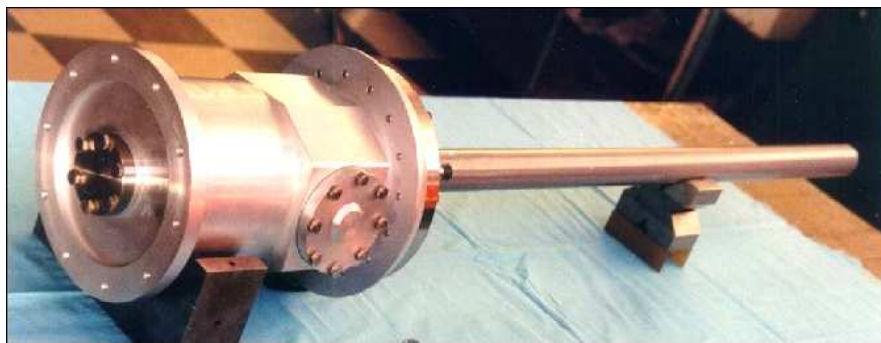


Target Region Components



Horn 1

Target Enclosure



6.4 x 28 mm² graphite segments.
1m long = 1.9 interaction lengths.
 $\mathcal{O}(100)$ KW beam power at 1 mm
beam width. Water cooled.

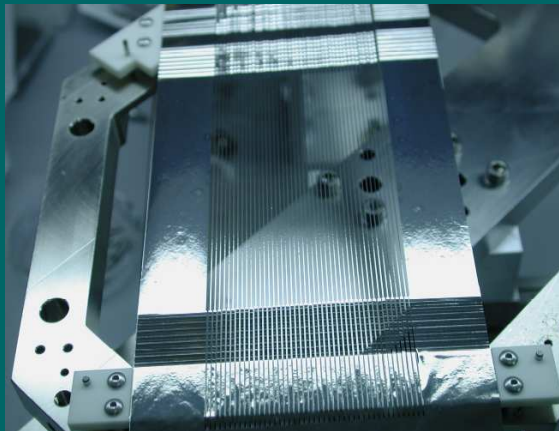


Parabolic magnetic lens.



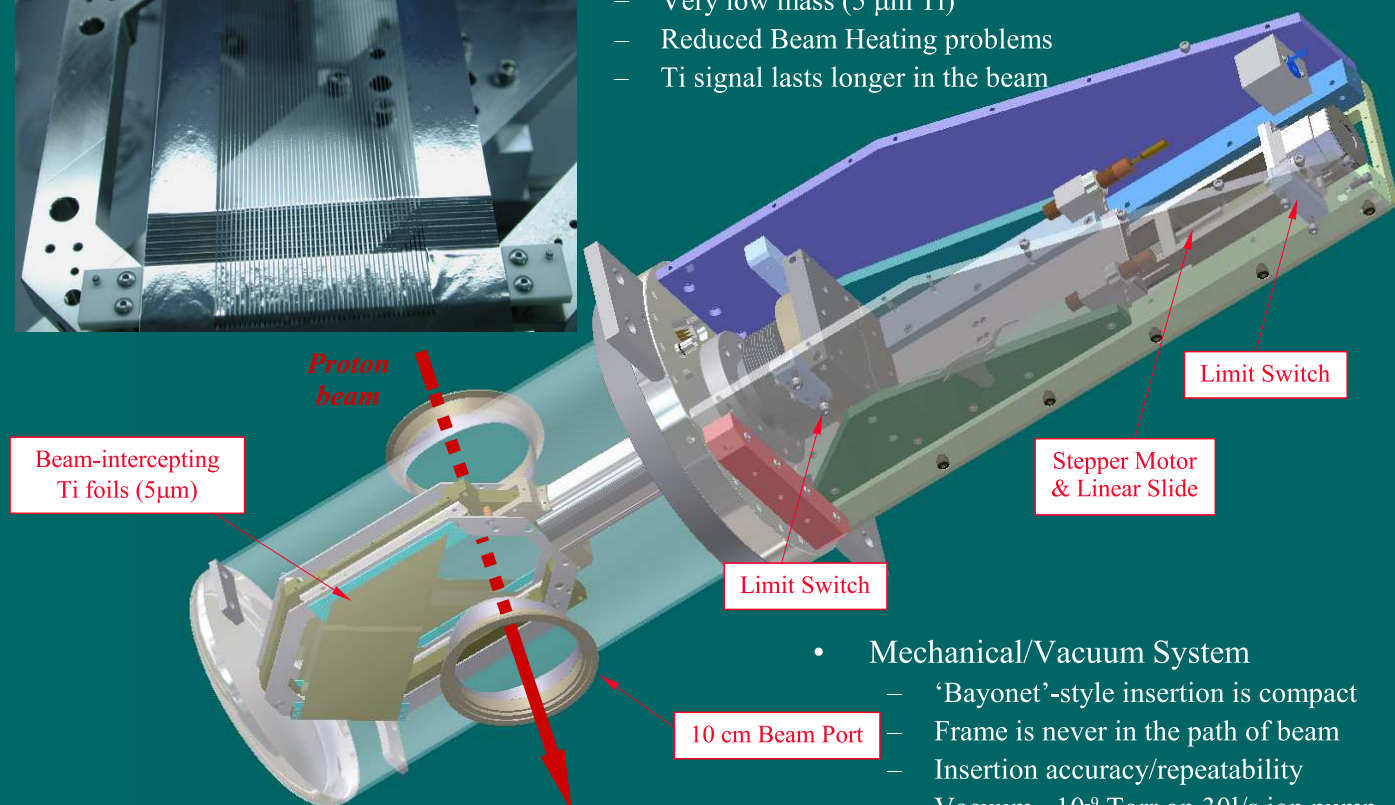
Measuring the Beam Profile

Segmented Foil SEM's



Foil Secondary Emission Monitors

- Beam profile + halo measurement
- Very low mass (5 μm Ti)
- Reduced Beam Heating problems
- Ti signal lasts longer in the beam



www.hep.utexas.edu/~kopp/minos/sem/

- Mechanical/Vacuum System
 - ‘Bayonet’-style insertion is compact
 - Frame is never in the path of beam
 - Insertion accuracy/repeatability
 - Vacuum $\sim 10^{-9}$ Torr on 30l/s ion pump



Measuring the Beam Position

Characteristics of NuMI Beam Position Monitors:

- Software algorithm to search 400 μsec to find the beam.
- NuMI bunches come in 6 batches from booster. Position is measured batch by batch.
- Linear over 15-20 mm. 50 μm resolution.



BPMs used to auto-steer the beam to target center



NuMI Beam Monitoring using JAS

M. Bishai

BNL has developed new online sophisticated monitoring software for the NuMI beamline instrumentation:

<http://minos.phy.bnl.gov/~bishai/minos/NuMIMon/>

The software uses the **JAVA Analysis Studio (JAS)** package to monitor NuMI beamline instrumentation data that is publicly available through FermiLab's Accelerator Controls Division XMI-RPC webserver. Features include:

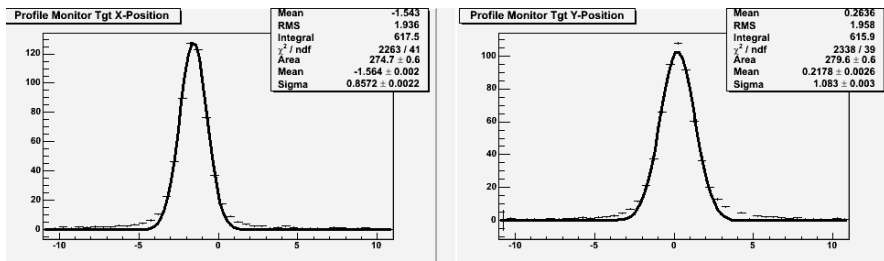
- Platform independent. Verified it runs under Windows XP, MAC, Linux.
- You can run it from any computer, any where \Rightarrow REMOTE MONITORING.



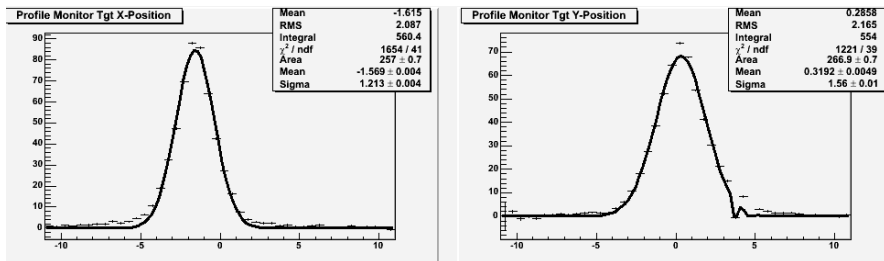
Beam quality studies - example

M. Bishai

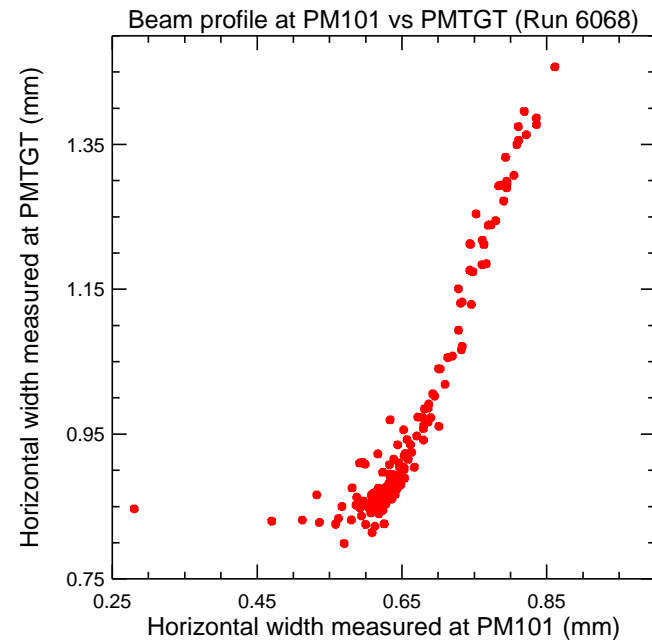
Beam width at target should be 1mm but booster (?) instabilities cause larger profiles:



Target beam profile , UTC timestamp = 1106417007.



Target beam profile, UTC timestamp = 1106420168.



Beam profile measured at target vs profile at Q101



MINOS Computing at BNL

B. Viren

<http://coop.phy.bnl.gov/~admin/doc/coop.html>

- Built BNL Physics Dept Cooperative Computing Cluster (COOP), an 18 CPU Opteron cluster (72x1 GHz Pentium equivalent).
- Cluster built from contributions from Physics Dept, MINOS, K0PI0 and Advanced Accelerator Group.
- 8/18 CPUs guaranteed for MINOS reconstruction, analysis and software development.
- MINOS is a heavy user of the COOP.
- Design allows for scalability to 100's of CPUs with constant administrative effort.



MINOS Database Inventory

M. Dierckxsens

- Maintaining the status of each of the database tables used in the MINOS offline software.
- Providing documentation about each of those tables for collaborators to easily obtain information about the large amount of DB tables.



Online Database Tables Inventory

Table Name	Table Czar	Info file avail.
FAB_VMM_LOC	Mark Dierckxsens	yes
FAB_VTM_CARD_LOC	Mark Dierckxsens	yes
FAB_WEINER_PS_LOC	Mark Dierckxsens	yes
PULSERTIMINGCARDSETTING	Nathaniel Tagg	yes

Calibration Tables

Table Name	Table Czar	Info file avail.
CALSTRIPATTEN	Nathaniel Tagg	yes
CALSTRIPSTRIPE	Phil Symes	yes
CALTEMPCALIBRATION	Chris Smith	yes
CALTIMEJUMP	Nathaniel Tagg	yes
PULSERTIMEDRIFT	Simona	yes

Data Collection & Processing Tables


Table Name	Table Czar	Info file avail.
CALDETBREMMOMENTUM	Mike Kordosky, Patricia Vahle	yes
CALDETCERRANGE	Mike Kordosky, Patricia Vahle	yes
CALDETCERTIMEWIN	Mike Kordosky, Patricia Vahle	yes
CALDETOVERLAPWIN	Mike Kordosky, Patricia Vahle	yes
CALDETTOFRANGE	Mike Kordosky, Patricia Vahle	yes
SPILLTIMEND	Nathaniel Tagg	yes

Database Logging Tables

Table Name	Table Czar	Info file avail.
DBLOGENTRY	Nick West	yes

Physical Properties & Monte Carlo Tables

Table Name	Table Czar	Info file avail.
PHOTONBLUESPECTRUM	Nathaniel Tagg	yes



FABCOMPONENT

Table Czar(s):
Mark Dierckxsens

Description:
This is the main table of a set that keeps track of changes to the hardware. Each component should have an entry in this table that tells what type of device it is (an int referring to DEVICE_ID in FABDEVICETYPE table), its serial number, the model and the manufacturer's name. Each time something has happened to a particular device and is entered into the database, the revision number gets increased. There is a comment column to record the reason for this change. A graphical user interface is under development to enter data into these tables.

Usage in the offline software:
This data is currently not used in the offline software.

Validation for entering new data:
Validation is done by the underlying classes of the user interface.

Process for automated filling:
Table not updated automatically or info not available.

Additional information:
More details about the HWDB tables and their development can be found [here](#).

Structure:

Field	Type	Description
SEQNO	int(11)	the sequence number
DEVICE_ID	int(11)	points to DEVICE_ID in FABDEVICETYPE table
SERIAL_NUM	varchar(20)	serial number of the component
MODEL	varchar(20)	the model of the component
MANUFACTURER	varchar(20)	the manufacturer's name
REVISION_NUM	int(11)	number of component changes
REVISION_REASON	text	comment field for revision reason

Updating status:

